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UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

FOREST AND RANGE RESEARCH

at the

FORT COLLINS RESEARCH CENTER

Rocky Mountain Forest and Range Experiment Station

(A Program Analysis)

by

L. D. LOVE

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PREPARED:

May 1, 1957

APPROVED:

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Date

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Director

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INTRODUCTION

This is a program analysis of forest and range research in the territory served by the Fort Collins Research Center. It has as its purpose the assembly of pertinent information into a single document wherein are described the research center territory, its importance and characteristics, resource problems and their significance, and what has been done toward the solution of the major problems. Included will be information of sufficient detail to appreciate the resource problems outlined and to appraise the forest and range research program of the center in the light of present day priorities. More detailed information is available in the specific references listed at the end of this analysis.

Research Center Territory

The Fort Collins Research Center serves the territory of central and eastern Colorado and southern Wyoming. (Fig. 1) The Center's territory embodies the central Rocky Mountains which form the headwaters of four national rivers; the Colorado, Rio Grande, Arkansas, and the North and South Plattes. These headwaters, ranging in elevation from 5,000 to 14,000 feet, provide the perennial streamflow which is needed at lower elevations for domestic, irrigation, and industrial uses. The relative streamflow of the four rivers from

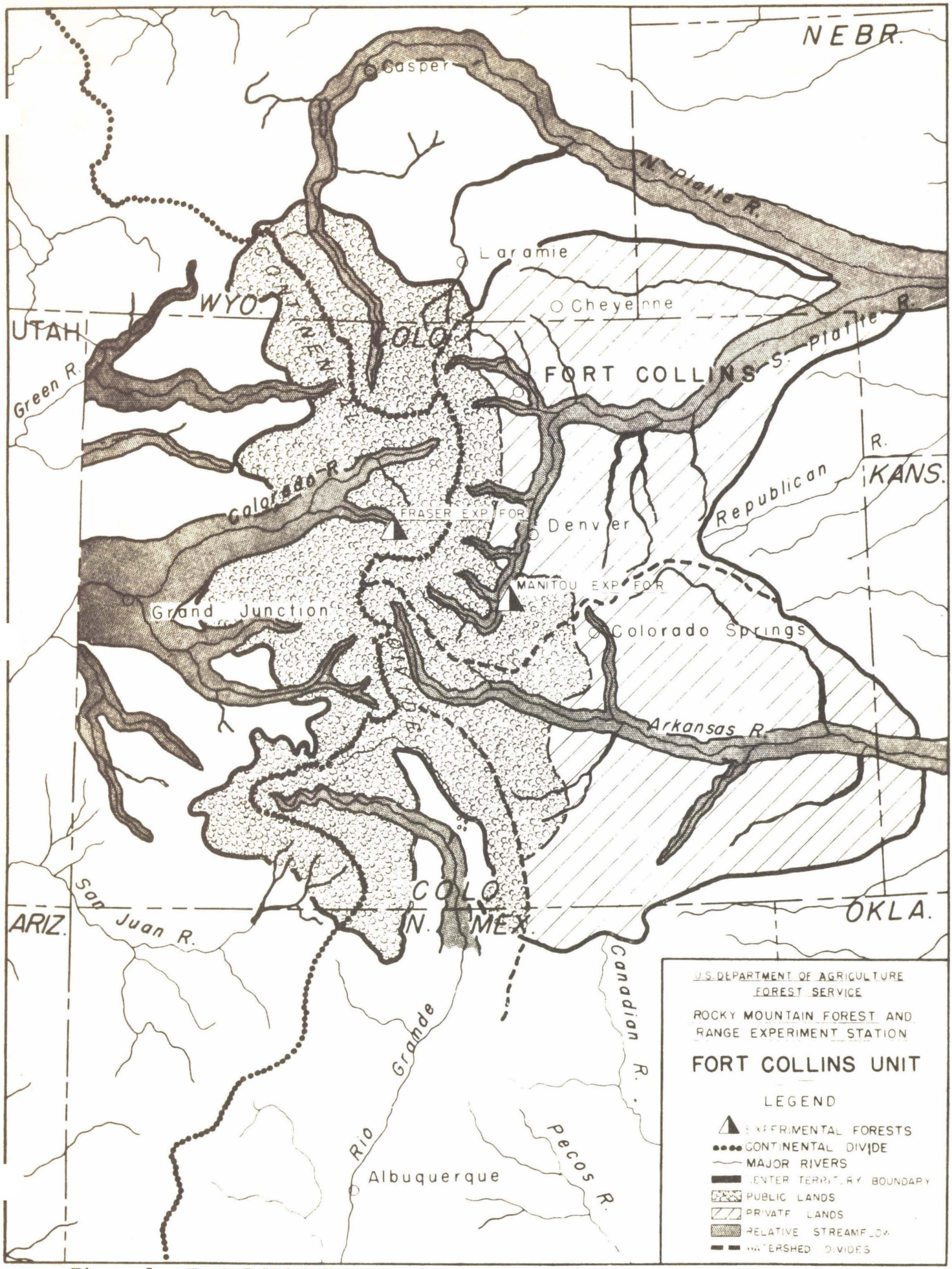

Figure 1.--Fort Collins Research Center Territory.

MAP # 8

their origin to where they leave the state line, is shown by the black bands on Figure 1. The bulk of the research activities of the Center are presently at the Fraser and Manitou Experimental Forests, and are confined to the ponderosa pine, Engelmann spruce-subalpine fir, lodgepole pine, aspen, and alpine grassland vegetation types.

Land ownership within the territory served by the Center falls into two broad categories. (Fig. 1) The eastern portion is predominantly privately-owned land (over 60 percent) and the western portion is predominantly publicly-owned land (over 70 percent). The eastern portion comprises the plains of Colorado and includes irrigated and dry farms, ranches, and sites of cities, towns, and villages. The western portion consists of the central Rocky Mountains and includes forested public lands, interspersed with private cultivated and ranch lands along valley stream bottoms and sites for numerous small towns and villages.

The resident population within the Center's territory is urban. Of 1,500,000 persons residing in the state of Colorado, half live in the city and county of Denver and adjacent counties. The centers of population are located east of the mountains in the plains portion. These centers are Fort Collins, Longmont, Greeley, Denver, Colorado Springs, Pueblo, and Trinidad. In the mountain portions are the towns of Idaho Springs, Steamboat Springs, Glenwood Springs, Gunnison, Durango, and Salida.

In the private-land portion of the Center's territory, considerable agricultural research is carried out by the Agricultural Research Service, the Colorado Experiment Station, sugar beet, and farm equipment companies. Such research includes demonstration farms, nurseries and greenhouses, livestock feeding pens, and field application of improved irrigation techniques. In addition, much of this research is brought to the private land owner through the efforts of the State Extension Service and the Soil Conservation Service.

In contrast, agricultural research in the public land portion of the Center's territory is primarily the concern of the Branch of Research of the United States Forest Service. A limited amount of research is done for private land owners by the Colorado Experiment Station and the Agricultural Research Service. Both the State Extension Service and the Soil Conservation Service are active in disseminating research results to private land owners.

This division of research activities between lands predominantly public and those predominantly private has caused a concentration of forest and range research by the Forest Service on the public lands. Such a division of effort has proven useful, and, as a consequence, the research program of the Fort Collins Research Center will adhere to that division. The discussions which follow, then, will be concerned with the forested public lands of the mountainous portion of the Center's territory.

Importance of Forest Research

The geographic location and natural resources of the territory served by the Fort Collins Research Center make it strategically important to the well-being and activities of 8,000,000 people and the economic stability of seven western states. Without the assurance of continued abundant supplies of clear water from its higher forest lands, the population of the arid West could not long be maintained at its present level. Intensive and profitable agriculture would no longer be possible; the development and growth of basic and secondary industries, including mineral extraction, atomic energy, pulpmills, and the trade and commerce dependent upon them, would become highly uncertain. (Fig. 2)

The source of most of this water is the national forests served by this research center and which are clothed with extensive stands of Engelmann spruce, subalpine fir, lodgepole pine, and ponderosa pine timber, and grazing lands. Water yield is here closely associated with high-elevation forest management practices, and its usability is dependent upon range management practices in the ponderosa pine forests below and the alpine areas above these forests, and how the timber is logged.

As a result of this situation, the Center is confronted with a complex multiple use problem. Forage is available for over 150,000 cattle and 565,000 sheep, but it can only be used if the method of doing so is economic and will not seriously affect water quality;

Figure 2.--Intensive and profitable agriculture depends upon water from distant mountains.

270 billion board-feet of timber are also available for use, but it can only be harvested in a manner that will provide for both a future forest and maintain or increase water yield, and, finally, timber must be logged both economically and without adding appreciable amounts of sediment to streams. To add to the complexity of the overall problem, this region has become one of the great playgrounds of the Nation, and any management practices developed for range, water, and timber must also give careful consideration to their effect on recreation.

In addition to the difficulties occasioned by multiple use, nature has contrived to add others which make the solution of many of the resource problems included in the Center's program unusually involved. To illustrate, forage in the ponderosa pine type occurs on soils that are highly unstable and rains which frequently fall at very high intensities are capable of doing extensive damage. A big game population of 250,000 deer and 40,000 elk add a complicating factor to range research that is not easily controlled. Rugged, highly variable terrain, relatively small timber, and the long winters of deep snow characteristic of the Center's territory, add together to make economic logging often impossible by conventional methods. Also, many watersheds are in need of restoration because of abuse in the past.

Located in the heart of the Rockies, with a broad research program in progress only 80 miles from Denver, the Center will take a leading role in the demonstration of multiple resource management.

Plans have recently been drawn up to enlarge the Center's physical facilities in order to meet the increasing demands placed upon it. These plans will be executed as rapidly as funds and time permit. In the immediate period ahead, special emphasis will be paid to the demonstration of logging methods, since they are the key to the efficient use of the timber resource and, under most conditions, also the key to increasing water yield. Subsequently, experimental watersheds will be managed on the basis of what research indicates to be in line with the best principles of multiple resource management.

Historical Background

The Engelmann spruce-subalpine fir, lodgepole pine forests of the central Rocky Mountains are often referred to as "Pioneer Forests." This expression is not accidental, but comes about through a series of events which have caused these forests to be one of the last mature forests to be harvested after settlement of the West. The age of the mature trees ranges from 250 to 300 years; establishing the mid-17th century as the beginning of their growth.

To trace the events in detail from the mid-17th century is not the purpose of this discussion; a brief review of the major happenings of settlement and use since that time will prove helpful in setting the stage for the principal problems as they are found today.

The mid-17th century saw the beginnings of Spanish settlement along the upper reaches of the Rio Grande in New Mexico. Aside from a few exploratory thrusts northward into eastern Colorado, these

settlements demanded little of the resources of the central Rocky Mountains. Spanish settlements were located adjacent to the major stream channels where irrigation farming and livestock grazing on the nearby uplands were practiced. Settlement by the Spanish of the Rio Grande portion of Colorado did not occur until the 1850's.

Until the advent of the fur trappers at the beginning of the 19th century, the central Rocky Mountains provided the hunting grounds and summer camps for the Plains Indians to the east and north. Large herds of deer, elk, antelope, and buffalo roamed the mountains during the summer months and migrated to lower elevations or to interior parks during the winter months. The impact of the Indians on the resources of the mountains was limited to a subsistence level and in no way did it disturb the existing natural environment.

Exploitation to the extent of disturbing this natural environment began with the fur trappers coming from Canada and from the eastern states. By 1825, beaver, which were once plentiful in the mountains, had become so scarce that the fur trade began to decline. Beaver dams that once delayed the flow of water down the major streams, broke and the natural environment began to change.

The trappers became guides to such noted explorers as Pike, Fremont, and Long. Such expeditions depended upon the resources of the mountains for food and shelter, but little else. They paved the way for a pattern of settlement which began with the discovery of gold in 1857 in the mountains west of Denver.

From then until the end of the 19th century, settlement was rapid in the mountains. Census figures show that the peak of population in Teller, Jefferson, Clear Creek, and Gilpin Counties was reached by 1900, only to decline to less than 20 percent, fifty years later. The bulk of these settlements and mining operations were concentrated in the ponderosa pine zone and it was this zone that provided the natural resources needed by the population. Here, also, began the first major disturbance in the natural environment.

During these years, the ponderosa pine zone provided forage for livestock, timber for buildings, and water for irrigation farming, domestic, and industrial uses. It provided an outlet for hunters, fishermen, campers, and picnickers. Its lands were used for the establishment and eventual abandonment of homesteads where the clearing of land for cultivation of slopes and valleys occurred. Mining enterprises within the type used the timber for props and fuel and charcoal for the smelters. The timber was a source of lumber for ties, bridge timbers, and stations of the early railroads. The land yielded crops and livestock to partially support these mining and railroad activities. With the decline of the production of the mines, the abandonment of the railroads, and the failure of the land and climate to support cultivated crops, the population shifted eastward to the towns and villages of the adjacent plains. Situated along the major streams which rose in the mountains to the West, these settlements were soon threatened by floods caused by summer thunderstorms centered on the depleted ponderosa pine lands.

Early settlement of the mountains was partially thwarted, but never halted, by widespread forest fires set by the Indians. These fires were not confined to single forest types; they extended from the plains to timberline. Forest fires did not stop with settlement, but became more widespread as the intensity of mining and railroad activities increased. It was not until the public forest lands had been under the jurisdiction of the United States Forest Service for several years that forest fires ceased to be a menace.

Following closely upon mining and railroad activities and the settlement of mountain and plains towns, came the development and practice of irrigation agriculture, in the early 1900's. Diversions, canals, and reservoirs were built so that the snowmelt waters from the mountains could be stored and used for the growing of cultivated crops. For the first time the mountains were looked to as a source of livelihood other than that found in the trees and grass growing on them. As the need for water for irrigation increased, more and more developments were undertaken. Today there exists a vast network of canals, ditches, and reservoirs, augmented by trans-mountain diversions, transporting water from western to eastern Colorado through the Continental Divide. In like manner, cities, as they have grown, have followed in the footsteps of the irrigation companies in augmenting their domestic and industrial needs for water.

Throughout all this activity of the occupancy, development, and use of the mountain lands, only the vast forests of Engelmann spruce, subalpine fir, and lodgepole pine escaped widespread use. These

mature forests suffered attacks from boring beetles, disease, and high winds to the extent that their production declined to less than 100 board-feet per acre annually. Following the second World War, the demand for lumber and pulpwood increased to the point where these forests are now being actively harvested. And, with this harvest, comes more water in the stream channels from the melting of winter snows. These forests are the "Pioneer Forests," because they are much the same as the pioneers found them.

The early day trapper and explorer were awed by the natural beauty of the mountains. The miner and railroader cursed the hardness of the natural rock, and the city dweller bemoaned the roar of rushing flood waters. But the mountains are still present and receptive to the onrush of present day explorers, miners, and dwellers as they come to the mountains to enjoy the vastness of rugged peaks, the rush of mountain streams, the occasional glimpse of game, the jump of trout in a beaver pond, the brisk winter air, and the restful nights.

These are what the early trappers found, and so the circle closes.

RESEARCH CENTER CHARACTERISTICS

The mountain portion of the Center's territory exhibits a great variety of land forms. These land forms range from the ancient, where the topography is undulating and the drainages stabilized with gently sloping banks, to the recent, where the topography is steep

and broken and the entrenched drainages have precipitous banks. Associated with the various land forms are the weathering characteristics of the parent rocks. Where weathering is slow, the resulting land form has a low density of drainages; where it is rapid, a high density of stream channels. A land form may have a block-like appearance; it may resemble a level plain; or it may be irregular and dissected by many drainages. Not only do the parent rocks influence the land forms, they also govern soil development.

The distribution of vegetation is influenced by land forms to some extent, but mostly it is governed by altitudinal changes, together with climatic differences. The different soils are found in all vegetation types and exhibit a variety of morphological characteristics, depending upon their altitudinal position and associated climate.

A useful way of considering the characteristics of the Center is by means of vegetation types. In this manner the soils, climate, and use can be related to the types which form the units for a forest and range research program.

Vegetation

The three predominant vegetation types in the mountain portion of the Center's territory are: (1) ponderosa pine-bunchgrass type, occurring between the elevations of 5,000 and 8,500 feet; (2) Engelmann spruce-subalpine fir, lodgepole pine, aspen type, found between the elevations of 8,500 and 11,500 feet; and (3) alpine grasslands, occupying lands above 11,500 feet in elevation. (Fig. 3) At the

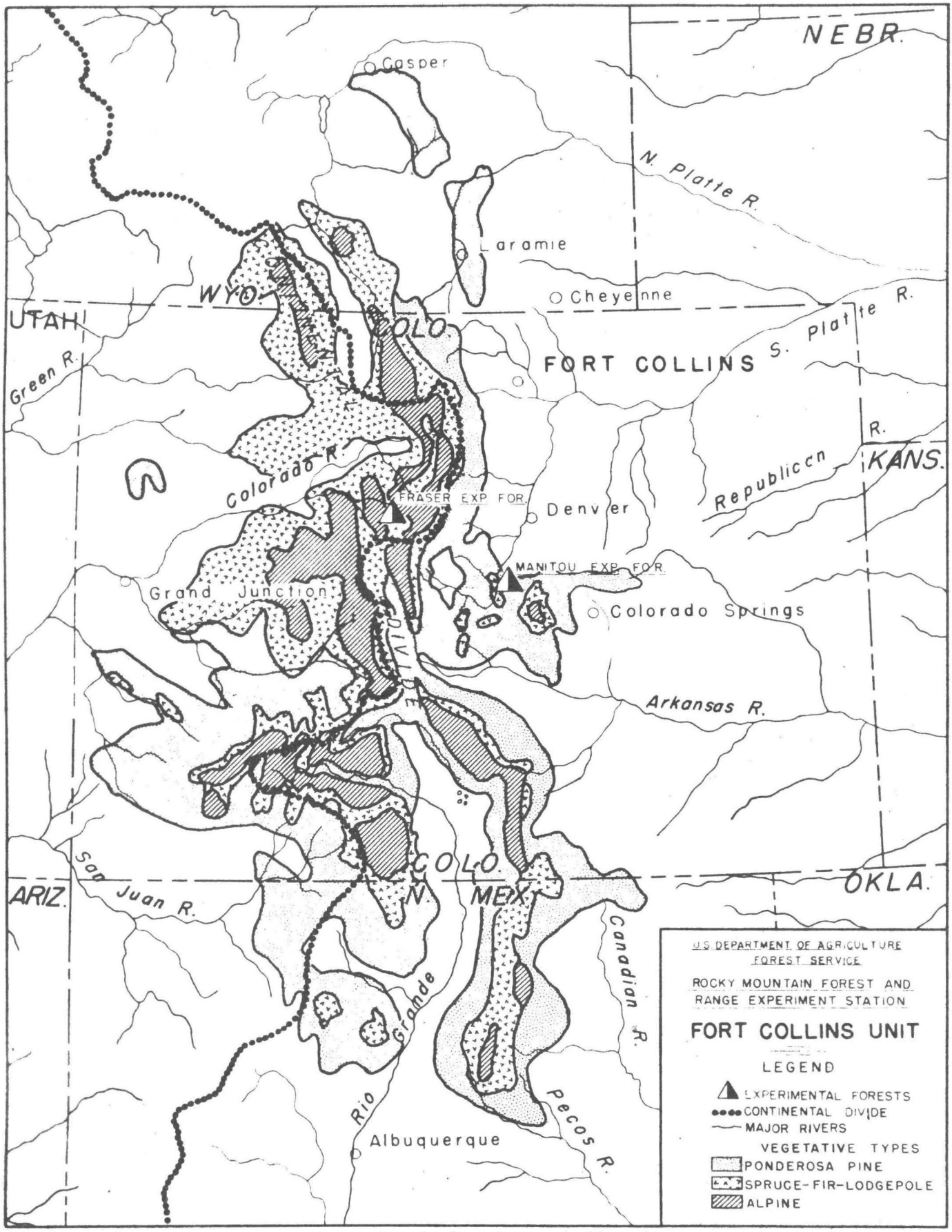

Figure 3.--Predominant vegetation types.

map #1

particular elevation where these types meet, they grade into one another. South exposures will contain the type of the lower elevation and north exposures that of the next higher elevation. These transition zones often complicate the management practices designed for individual types.

The western portion of the ponderosa pine-bunchgrass type gradually merges with the spruce-fir zone, or the lodgepole pine zone where it occurs. Along the eastern margin, a series of north-south hogbacks and foothills are covered with a mixture of ponderosa pine, mountain brush, and native grasses. In the southern portion, the eastern areas support stands of pinon-juniper that intergrade with ponderosa pine as the land slopes upward to the West. The ponderosa pine type occupies about 17 million acres of land.

The ponderosa pine-bunchgrass type includes four vegetation subtypes of special interest: open stands of timber with an extensive herbaceous understory of Arizona fescue, mountain muhly, sedges, blue grama, Parryi danthonia, and a variety of weeds, (Fig. 4); open grass parks, devoid of trees and consisting of a denser stand of the same herbaceous species; meadows and streambanks covered with sedges, rushes, hair-grasses, wheatgrasses, and willows, (Fig. 5); and closed stands of ponderosa pine with no understory, but with a litter mat of needles and small twigs, (Fig. 6) or, at higher elevations or on north exposures, mixtures of pine and Douglas-fir. Grass cover varies in density from lush meadows to an extremely thin and patchy cover on steep, unstable, south-facing slopes. In the southern half of the

Figure 4.--Open stand of ponderosa pine with an herbaceous understory.

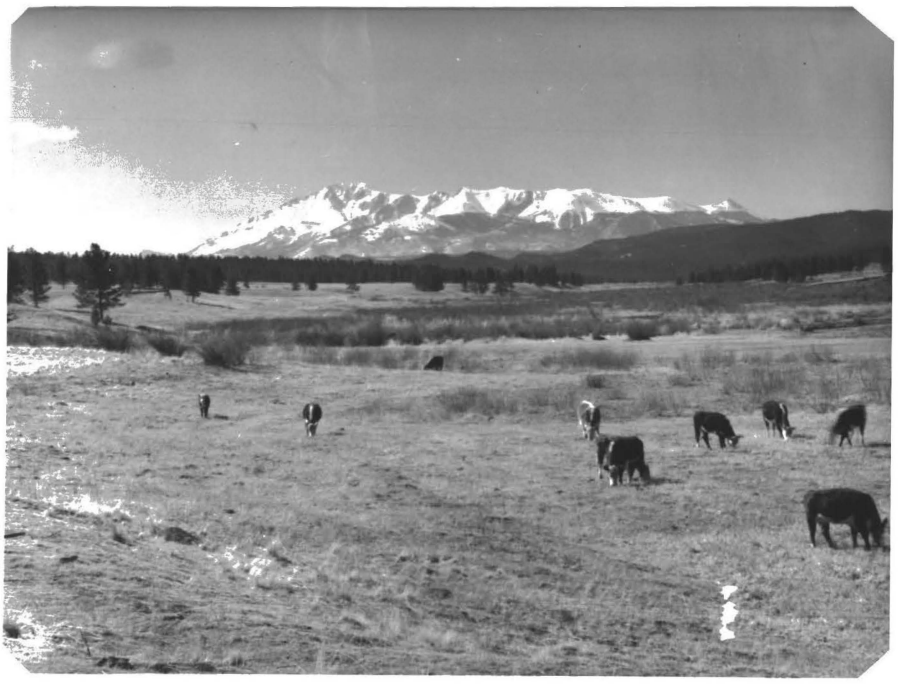

Figure 5.--Meadow adjacent to a stream in ponderosa pine type.

Figure 6.--Dense stand of ponderosa pine with no herbaceous understory.

ponderosa pine type, oak brush has invaded cutover pine stands. In many places, the oak brush is of sufficient density to be classified as a separate type.

The forest types of Engelmann spruce-subalpine fir, lodgepole pine, and aspen comprise the subalpine zone of vegetation. In area, it is approximately 14.5 million acres. Although no accurate figures are yet available on areas of the individual forest types, they are estimated as follows:

Engelmann spruce-subalpine fir	7.0	million acres
Lodgepole pine	5.5	" "
Aspen	2.0	" "
Total	14.5	" "

On any given area, all three forest types are likely to be found. On north and east slopes, the spruce-fir type usually extends throughout the elevational range of the zone. On south slopes, lodgepole pine may cover the complete range of elevation.

Aspen may occur on any aspect, but is limited to elevations below 10,500 feet. In general, it appears to be a persistent type only on exceptionally wet areas and where recurrent snowslides wipe out the coniferous species that depend on reproduction from seed. (Fig. 7)

The spruce-fir and lodgepole pine forests of the subalpine zone are characterized by high density. This is particularly true of the spruce-fir type, where a closed, high canopy is normally supplemented by a partial understory. (Fig. 8) It is less true in the lodgepole

Figure 7.--Aspen at beginning of snowmelt period.

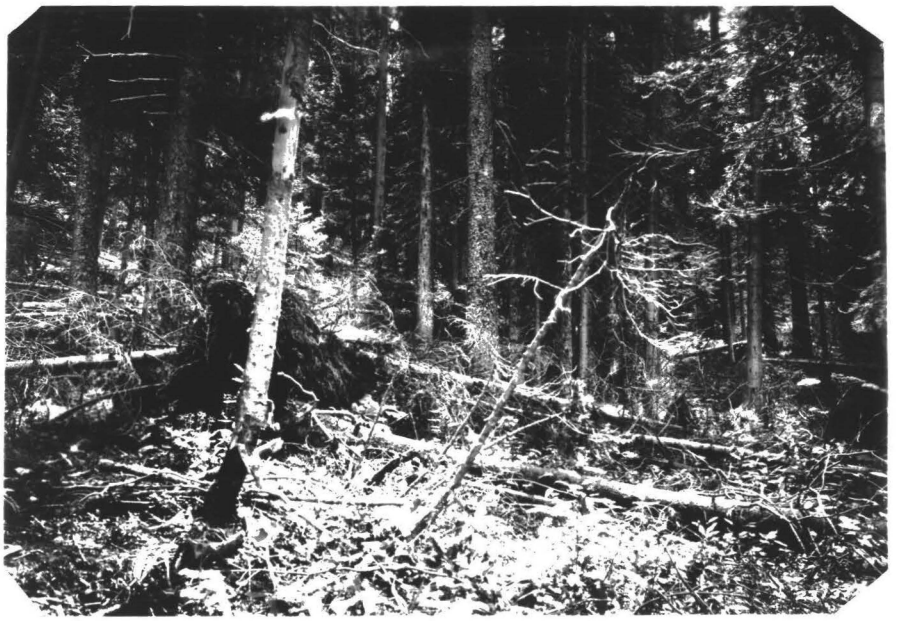

Figure 8.--Engelmann spruce-subalpine fir type with characteristic understory.

type. Here, the overstory commonly has a closed canopy, but an understory is usually lacking. (Fig. 9) Aspen stands often contain an understory of spruce, fir, or pine.

Alpine grasslands of the central Rocky Mountains encompass approximately 5 million acres. They are found in a series of discontinuous segments, occupying the tops of the higher mountain masses above the spruce-fir forests. Because the transition zone between true forest and treeless grassland contains considerable usable livestock forage, it is included with the grassland.

The vegetation of the alpine region is seemingly without pattern due to numerous local site differences. Notwithstanding this complexity, floristic composition is remarkably uniform and can be grouped as woodland, grassland, and desert. (Fig. 10) The transition between forest and grassland is dominated by stunted, decumbent groups of individuals similar in species to those of the forest below. Interspersed between the scrubby trees are herbaceous species which extend downward from the grassland.

Most alpine ranges have a high percentage of plant and litter cover. Herbage production varies greatly, ranging from 58 pounds per acre air-dry on one site, to 1,304 pounds per acre on another. On the drier, well-drained slopes and ridges production averages 328 pounds per acre, while on the more moist sites it averages 647 pounds per acre.

Figure 9.--Lodgepole pine type with characteristic understory.

Figure 10.--The alpine zone above the subalpine spruce-fir forests includes woodland or Krummholz, grassland and desert plant communities.

In the grassland aspect, all gradations from dry to extremely wet sites are encountered. The amount and duration of the winter snows and exposure are primarily responsible for these differences, although soil, drainage, and other features are also important. Where the soil remains moist throughout much of the growing season, several grasses and sedges dominate the plant cover. Sites which are subjected to extreme exposure, low temperatures, and poor soil and water conditions have a sparse vegetative cover of mat or cushion forms of plant species.

On certain sites within the grassland complex, relatively dense stands of willows (Salix spp.) are found. There are wide differences in growth form between the several species; some are upright, typical shrubs, but others are low and mat-like. (Fig. 11)

Geology and Soils

A diversity of soils occurs in the mountains. They may be grouped into three general classes, however, (Fig. 12) There are soils developed from the metamorphic rocks of granite, schist, and gneiss; soils developed from the igneous rocks of basalt, andesite, and rhyolite; and soils developed from the sedimentary rocks of shale, sandstone, and limestone.

These soils exhibit distinct characteristics of fertility, water absorption, internal drainage, profile development, and stability. They react differently under the same kind of management. The same vegetation growing on them will vary in density, composition,

Figure 11.--Erect and decumbent willows growing on the same alpine area.

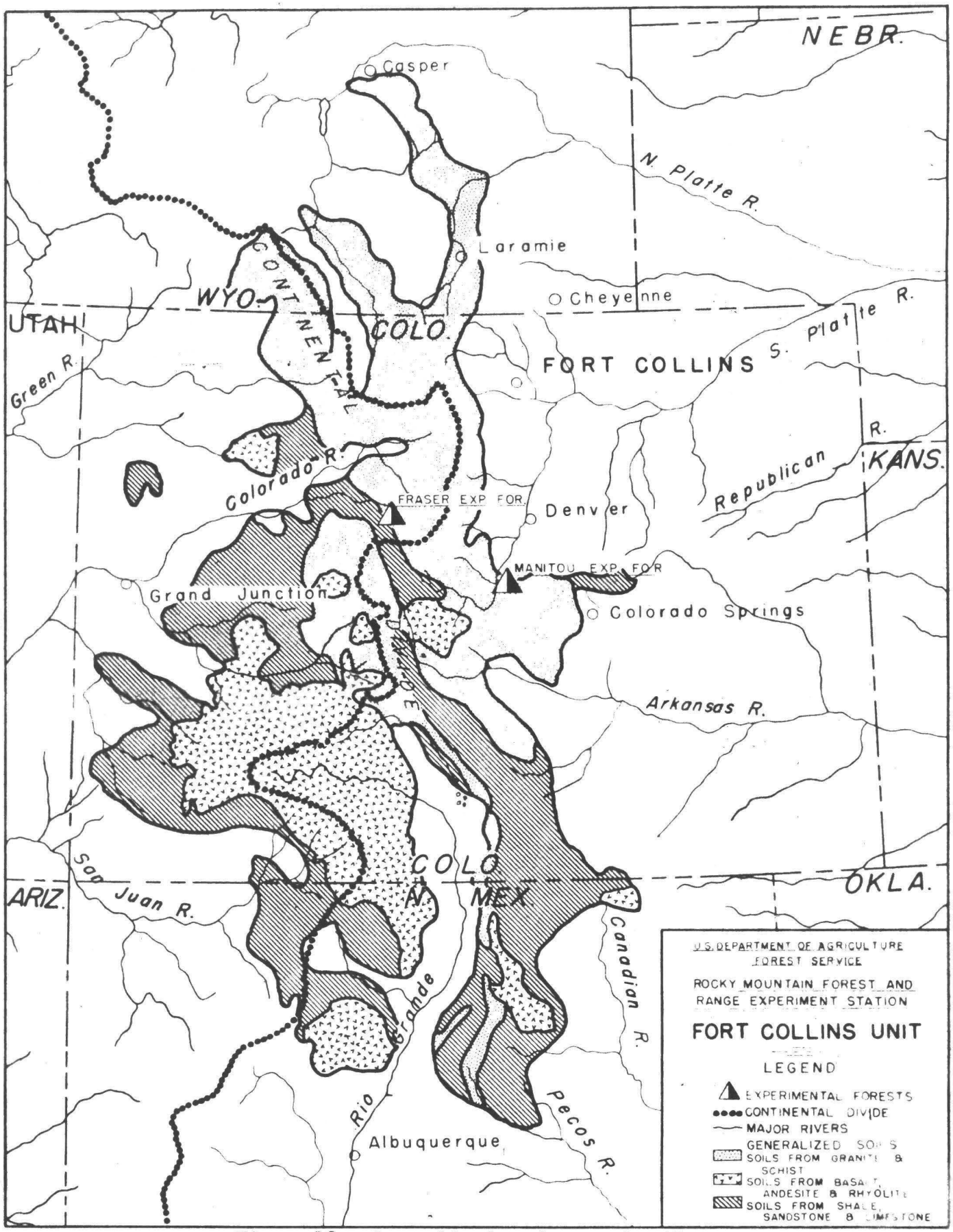

Figure 12.--Generalized geology and soils.

and rate of growth. These soils will exhibit different profile characteristics when found on north and south exposures at the same elevation.

Thus, soil depth and morphological development fluctuates between the three broad geologic parent rocks. Shallow soils occur on the upper slopes of the mountains and become gradually deeper toward the toe or lower slopes. Along the valley bottoms occur alluvial soils, developed from a mixture of geological materials. Soils developed from glacial till are found in the upper reaches of mountain valleys.

Only a few of the great variety of soils occurring in the mountains will be described. The descriptions will serve to illustrate the major soil differences important in land management. The soils will be correlated with the three major vegetation types previously described.

In general, the soils of the ponderosa pine type have developed from schist, granite, and shale. Localized areas of soils developed from igneous rocks, limestone, and sandstone occur scattered throughout the type. The three principal soils exhibit different characteristics and will respond differently under similar use.

Soils developed from schist (Fig. 13) have a fine, sandy loam surface soil, gray-brown in color, and a granular structure. They vary in depth up to 20 inches, and the surface soil grades into the parent rock. Subsoils are generally absent. The parent rock is often weathered and cracked which facilitates the movement of water

Figure 13.--Shallow residual soil formed on biotite schist. Note weathered character of the parent rock.

into the sub-strata. Soils on the south exposures are drier than those on the north, and contain less surface litter and organic matter.

Soils developed from granite may or may not have clay subsoils. Those without have a gravelly, sandy loam surface soil, 4 to 8 inches thick, which grades into the parent rock. The latter may be weathered and crumbly, or unweathered and massive. Soils on south slopes are drier and contain less surface litter and organic matter than those on the north. Soils without subsoils are characteristically red-brown in color and are the most extensive soils in the ponderosa pine-bunchgrass type. Where litter or plant cover is absent, the surface is protected by a gravel pavement beneath which lies a layer of fine-textured material. Only on the north and east exposures do these soils exhibit any podsolization characteristic of forest soils. Acidity ranges from pH 5.5 to 6.5.

Soils with clay subsoils are less extensive than those discussed above. They may be residual in nature, or developed on old alluvial terraces, consisting of granitic materials. (Fig. 14) The surface soils are 8 to 10 inches thick, reddish-brown in color, and of a coarse, sandy loam texture. They are underlain by a red clay subsoil that may be 2 or more feet in depth. This subsoil is compact and well cemented when dry. At the base of the subsoil, lime deposits on small gravels are occasionally found. The parent material is often decomposed, and consists of a reddish-brown gravel. A

Figure 14.--Soil developed from granite and having a clay subsoil. Subsoil is a blocky structure. Lime zone at bottom.

Figure 15.--A deep soil developed from shale having a clay subsoil.

gravel pavement occurs where the soil surface is devoid of litter or plant cover.

These two soils, developed from granite, differ from each other hydrologically by having different characteristics of moisture retention and internal drainage.

Soils developed from shales exhibit a variety of characteristics, depending upon exposure and kind of plant cover occurring on them. Soils on south exposures are shallow with surface soils ranging from 6 to 12 inches thick, gray in color, clay to clay loam in texture, and grading into the parent material. Soils on north exposures or those covered with a dense stand of pine, oak brush, or grass have surface soils 8 to 18 inches thick, brownish-gray in color, and clay to clay loam in texture. (Fig. 15) Beneath the surface soils occur block-like subsurface soils of varying thickness, gray in color, predominantly clay in texture and grading into the parent material. Both soils are basic in reaction and may or may not have calcium deposits in their profiles. Both are fertile, but are subject to excessive sheet erosion when devoid of an adequate plant cover. Internal drainage is slow and moisture retention is high.

Associated with these three major soils are alluvial soils occurring in valley bottoms and in upland pockets formed behind rock outcrops. The alluvial soils are generally deep, have only surface soils 6 to 18 inches thick, brown to dark brown in color, of varying textures, neutral in reaction and grading into the parent alluvial

material which is often loose and porous. (Fig. 16) These soils have considerable moisture storage capacity, but are easily eroded once gullies start in the valleys. They are commonly covered with grass or low shrubs.

The soils of the Engelmann spruce-subalpine fir, lodgepole pine, aspen type are varied in origin. The greater portion of parent bedrocks consist of granites, gneisses, schists, and igneous rocks. Glaciation has left its mark in numerous moraines. Flood plains of coarse gravel and cobbles are common along lower reaches of the streams.

Regardless of origin, it is characteristic of the soils that they are coarse in texture and porous. Weathering is slow at these high elevations and, thus, the proportion of clay is low while that of gravel is high. Soil materials (regolith) are usually deep, allowing deep water penetration and storage. (Fig. 17) Abundant litter prevails, but on south slopes is often thin, with mineral soil spottily exposed.

Perhaps of greater significance are the differences found in soils developed on north and south exposures at the same elevation. These differences will materially affect the hydrologic and silvicultural aspects of a management program.

Soils on north exposures (Fig. 18) are developed under a spruce-fir stand. The surface is protected by a dense litter layer consisting of moss, lichens, and dead twigs and needles. Vaccinium grows dense and vigorous.

Figure 16.--A deep alluvial soil found in mountain valleys.

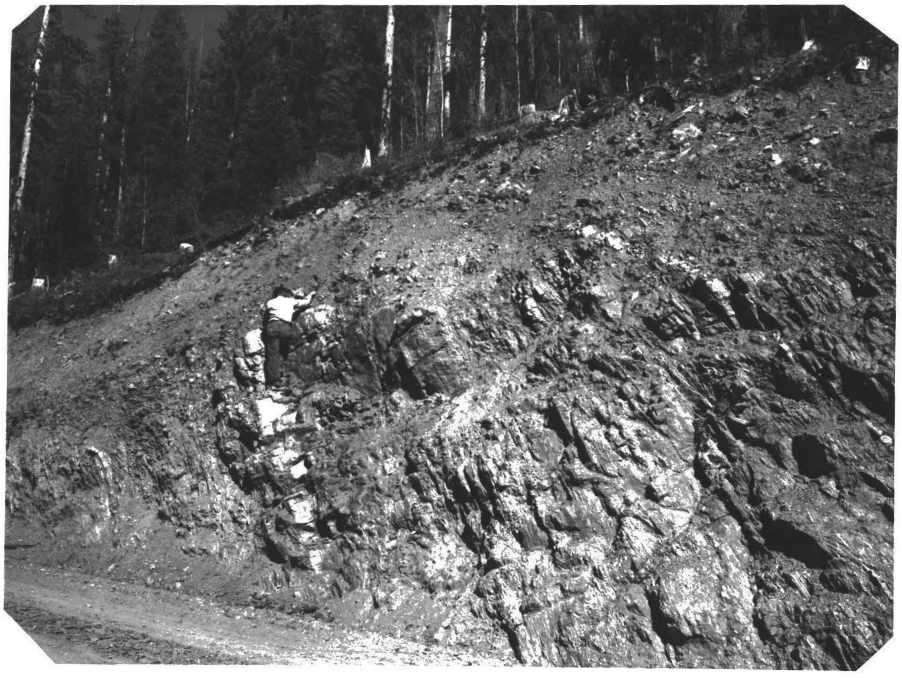

Figure 17.--Soil materials are often deep over bedrock, allowing for deep water storage.

Figure 18.--Soil developed from schist on a north exposure under a stand of spruce and fir.

Below the litter layer occurs a light gray, dusty, bleached layer 2 to 6 inches thick. Beneath the gray layer is a light yellowish-brown layer, 8 to 15 inches thick, characteristic of the spruce-fir type. Both these horizons are acid. A third layer, 12 to 18 inches thick, next occurs, olive-gray and brown streaked in color, cemented by silt and clay particles on the faces of small rocks and in small soil pockets. Following this layer is the parent soil material of varying thickness, grayish in color, loose and open with occasional large rocks.

In contrast are the soils of south exposures developed under lodgepole pine. (Fig. 19) The surface is protected by a thin litter layer, consisting of needles, twigs, and cones, and a sparse growth of vaccinium. Beneath the litter layer may or may not occur a thin gray acid layer, seldom over 3 inches thick, if present. Following this is a brown layer, 4 to 12 inches thick, loose and friable, and grading into the parent soil material. The latter is of varying thickness, olive-gray in color and consisting of angular fragments of gravel with little fine material, but with considerable coarse sand.

The two soils discussed above are distinctly different and will react differently under the same type of management. The soils of north exposures are podsolized brown forest soils, while those of the south exposures are brown forest soils. One exhibits a profile development, the other does not. Both differ hydrologically in moisture retention and in internal drainage.

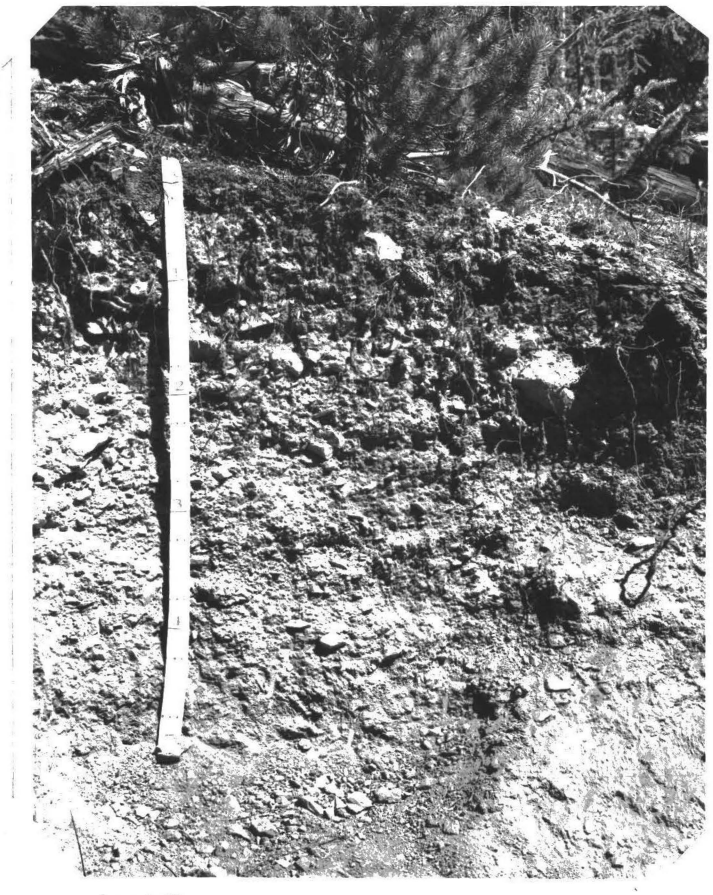

Figure 19.--Soil developed from schist on a south exposure under a stand of lodgepole pine.

Another important soil occurring in the spruce-fir, lodgepole pine, aspen type is the one developed on glacial till. (Fig. 20) This soil will have the same profile characteristics as those discussed previously when the glacial till occurs under a stand of lodgepole on the one hand and a stand of spruce-fir on the other. In both instances, soils developed from glacial till will have greater internal drainage, considerably less moisture retention, and little susceptibility to erosion under timber harvesting and road building.

The nature of the parent soil materials which consist of many rounded rocks and boulders and coarse soil particles, make this soil one of the most stable of the mountain soils.

Soils developed from igneous rocks under the Engelmann spruce-subalpine fir, lodgepole pine, aspen forests are dark-brown to brown in color and show evidence of podsolization. Considerable litter covers the soil surface and, under trees, may be several inches thick. The dark-brown surface soil, with streaks of gray-brown, varies from 4 to 8 inches in thickness, clay to clay loam in texture, and is acidic in reaction. The subsoils are a brown clay, 8 to 18 inches thick, fairly compact and neutral or acidic in reaction. The parent material is light brown in color and weathered or fractured in its upper portions. Scattered rocks are found throughout the entire profile. These soils absorb water at a medium rate, have a high moisture retention capacity, and good internal drainage. They are relatively fertile and stable, and do not erode easily.

Figure 20.--Soil developed from glacial till. Profile characteristics depend upon the forest stand growing on it.

Alpine soils are found on almost all degrees of slopes and are normally held in place by a dense, tough sod cover. (Fig. 21) On the well-drained slopes and ridges the surface soils are usually black, and about 7 inches thick. The subsoils are variations of brown. In basins or depressions, the soils are dark and have a high organic content. If water is ponded for all or part of the year, the soils are peaty with little mineral soil present. The texture, except in the bog soils, is commonly a loamy sand or gravel. Rock fragments are abundant throughout the subsoil. There is usually only a weak, granular structural development. In most cases the soils are acidic, pH ranging between 5.0 and 6.0, except on a calcareous soil.

Climate and Water Yield

Effective climate is used as a basis for describing climate and water yield of the mountain portion of the Center's territory. Effective climate is the difference between potential evapo-transpiration and annual precipitation. This difference results in indices useful in classifying climate and, for the Center's territory, results in humid, subhumid, and semi-arid climates. (Fig. 22)

Humid climate is associated with the Engelmann spruce-subalpine fir, lodgepole pine, aspen type and the alpine grasslands. Annual precipitation is in excess of potential evapo-transpiration throughout the year. As a result, streams originating in this climate are

Figure 21.--Soil developed from schist, under alpine grassland.

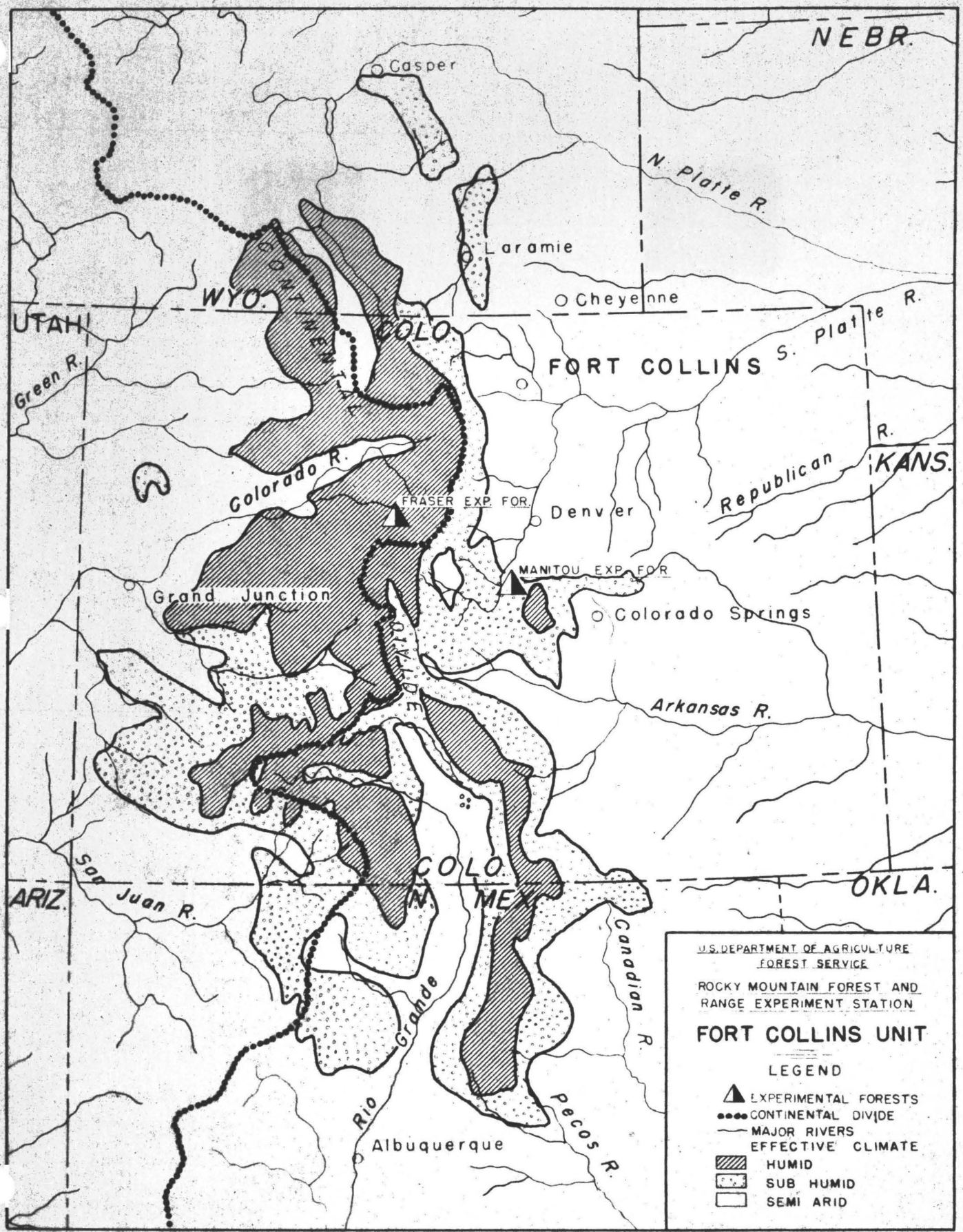

Figure 22.--Effective climate.

perennial and water is in excess of the demands of the native vegetation. The humid climate has cold winters and mild summers and, generally, occurs at elevations above 8,500 feet. Winter snows are stored on the ground until spring thaws, when the streams become swollen from snowmelt waters. Deep seepage through the soil mantle takes place during the spring and early summer, allowing for a long period of drain-out with the streams maintaining a relatively constant flow.

Subhumid climate is associated with the ponderosa pine-bunchgrass type. Annual precipitation is in excess of potential evapo-transpiration only during a portion of the year. As a result, streams originating in this climate are often intermittent and flow only during the fall, winter, and spring months. The subhumid climate has mild winters and warm summers, and occurs at elevations from 6,000 to 8,500 feet. Winter snows generally melt soon after their occurrence, except on isolated north exposures. Summer cloudburst storms occur in this climate and often result in damaging storm flows. The cloudburst storms, when of sufficient frequency, aid in maintaining streamflow in streams originating in this climate.

The semi-arid climate occurs at elevations below 6,000 feet (except in certain isolated interior mountain parks; i.e., South Park, San Luis Valley). It is associated with pinon-juniper, sagebrush, and plains grassland types and with irrigated and dryland farming areas. Potential evapo-transpiration is always in excess of annual precipitation and it is only during cloudburst storms or after heavy

winter snows that the streams originating in this climate will contain flowing water. The semi-arid climate generally has mild winters and hot summers.

In the semi-arid climate are found the major cities and towns, as well as vast acreages of irrigated land. Many industries, both large and small, are also located in this climate. The water originating in the humid and subhumid climates furnishes the semi-arid climate with the necessary supply for domestic, irrigation, and industrial uses.

Water yield from the mountain lands of the Center's territory follows closely the effective climate with highest yields coming from the humid climate and lowest from the semi-arid. (Fig. 23) Yields of 18 acre-inches per acre or more come from the alpine grasslands and from that area of dwarf trees at timberline. Dense forests of Engelmann spruce, subalpine fir, lodgepole pine, and aspen yield from 6 to 18 acre-inches per acre from areas above 8,500 feet in elevation. The ponderosa pine type yields from 3 to 6 acre-inches per acre between the elevations of 6,000 and 8,500 feet. In contrast, the areas within the semi-arid climate yield from 0 to 3 acre-inches per acre.

Of the approximately 27,000,000 acre-feet of water yielded annually from the mountain portion of the Center's territory, 35 percent comes from alpine grasslands, 50 percent from Engelmann spruce-subalpine fir, lodgepole pine, aspen forests, and 15 percent from ponderosa pine-bunchgrass ranges.

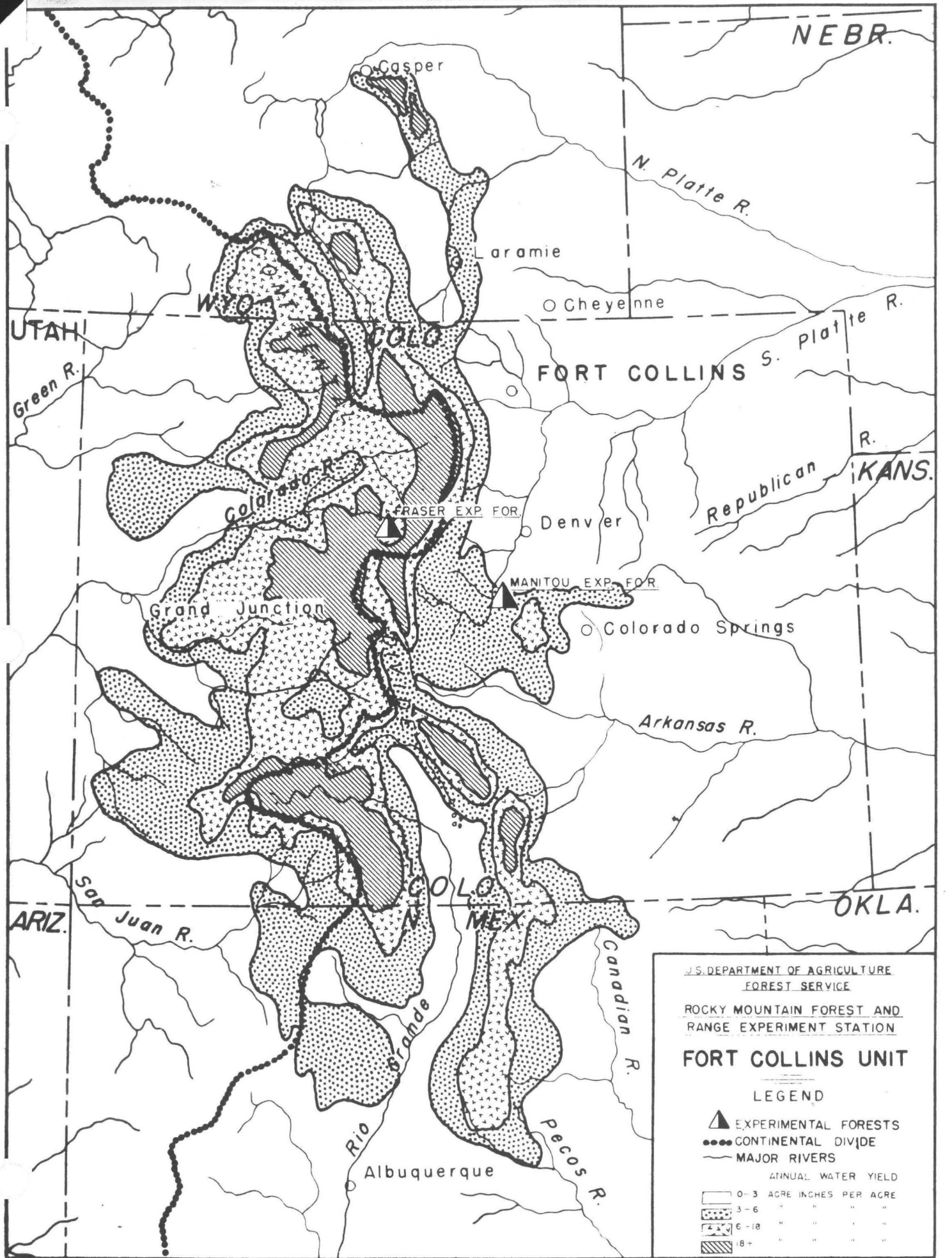

Figure 23.--Annual water yield.

Map #7

Present Use

Present day use of the mountain portion of the Center's territory is difficult to measure in specific terms. Many on-site uses are interrelated, such as timber and forage production, water yield, and recreation; other products may be consumed some distance away from their origin, such as livestock products -- hides, meat, and wool -- and forest products -- poles, posts, and paper. Water originating in the mountains may be used to produce crops several hundred miles away; or it may be used for steel manufacture or oil refining soon after a stream emerges from the mountains.

Present day use means much to many people, but it can be expressed only in general terms. (Fig. 24) For example, it means the livelihood of 4,500,000 resident people, many of whom live outside the Center's territory in 90 cities of over 5,000 population each. It means the irrigation of 6,000,000 acres of land, about half of which is located outside the Center's territory, but all of which depends upon water yielded within the territory. It means much to nearly 5,000,000 visitors who come from all parts of the United States. It has also meant much to the economy of the Nation in terms of the many millions of dollars obtained through the mining of gold, silver, lead, and copper.

Absolute figures of use have little meaning in terms of present day problems. Trends in use do. What is the trend in livestock use, in timber production, in recreation, and in water use? Such trends in use point up the priority one use may have over another.

Figure 24.--Present day use means much to many people.

The trend in water use is closely tied with population growth, especially in the West. Population increases from 1940 to 1950 amounted to 53 percent for California, 50 percent for Arizona, 28 percent for New Mexico, 18 percent for Colorado, and 16 percent for Wyoming, for example. During the 50 years, 1900 to 1950, the West has experienced a growth in population of 378 percent compared to 98 percent nationally. During this same period, the average national per capita rate of withdrawal of water for use has doubled. If this national rate is applied to the West, in combination with population growth and per capita requirements, an increase in water demand of 800 percent during the 50-year period is indicated. (Fig. 25) This increase in demand does not take into account increases needed for irrigation or industry.

The trend in water use is upward. One might conclude that the average annual increase in water use will approximate 20 percent when viewed from expected population growth during the next 25 years. In contrast, it is hardly to be expected that the climate which prevails in the West will be capable of supplying water for this increased demand. A more satisfactory adjustment would appear to be one of restricted use for the good of all concerned. This appears to be what has happened during recent years in such cities as Fort Collins, Denver, Colorado Springs, Pueblo, and Albuquerque.

During the past 7 years, the trend in timber cut on National Forests in Colorado has been upward. The bulk of the Center's territory includes these forests. The amount of timber cut for sawtimber,

Figure 25.--A transmountin diversion under construction to meet water needs for a growing population.

pulpwood, poles, mine props, and posts during the years 1950-56 on Colorado National Forests was as follows:

Year	Board-feet
1950	111,850,000
1951	128,067,000
1952	125,660,000
1953	134,066,000
1954	132,696,000
1955	153,123,000
1956	184,913,000

The slow increase over the years of the timber cut can be attributed to the increased harvesting of mature stands of Engelmann spruce and lodgepole pine. (Fig. 26) Such increased harvesting is desirable from a management standpoint as it enables new forests to become established so that modern methods of silviculture can be applied. The demand for forest products is on the increase and it is expected that it will remain so as population growth continues.

In contrast, livestock use of the Colorado National Forests is downward in trend. This is indicated by the following summary of the number of animals grazing these forests:

Year	Cattle and Horses	Sheep and Goats
1940	306,656	821,545
1945	366,000	810,000
1952	150,442	591,805
1955	152,887	564,731

Figure 26.--Harvesting mature Engelmann spruce trees has increased.

Not only have livestock numbers decreased, the numbers of permittees on Colorado National Forests have also decreased. For example, in 1940 there were 3,506 cattle permittees; in 1955, 1,847. In 1940 there were 2,484 sheep permittees; in 1955, 484. Declines in the number of livestock and number of permittees indicate a basic change in rangeland agriculture in the Center's territory. (Fig. 27) The consequences of this change are yet to be felt on other uses of the mountain lands as the period of time involved is too short.

Meanwhile, use of the mountain lands by hunters and fishermen has steadily increased. Big game and fish are dependent upon the products of the forest, forage and water, and as the forests are opened up through access roads, more and more people engage in hunting and fishing. The trend in this use is indicated by the number of hunting and fishing licenses sold in Colorado during the past 30 years.

Year	Total number Resident and Non-Resident
1920	107,914
1930	120,868
1940	198,631
1949	404,796
1950	519,981

The trend in the number of visitors to the Colorado National Forests also illustrates the use to which the mountain lands are now being subjected. In addition, there has been an increase in summer home construction.

Figure 27.--Sheep grazing alpine grasslands.

Year	Total visitors	Summer homes
1920	1,200,000	---
1930	2,340,660	496
1939	2,739,000	---
1949	2,400,000	700
1953	3,623,295	807
1955	4,857,808	---

Visits to the Colorado National Forests are concerned with many activities. More and more, these forests are becoming a national playground for Americans with much leisure time. Major activities during visits to the Colorado National Forests are shown below:

Year	General Enjoyment	Hunting & Fishing	Picnicking	Winter Sports	Hiking & Riding	Camping
	Number					
1941	566,508	416,263	289,432	85,137	63,578	47,024
1950	849,380	635,930	435,325	138,480	71,951	66,300
1955	1,931,925	1,235,041	1,024,052	246,080	113,790	229,917

The trend in recreational use is upward. The enjoyment of recreational visits to Colorado National Forests depends on the trees, grass, and water produced on them. (Fig. 28) Here, a major new use begins to infringe on older uses.

In summary, present use of the mountain portion of the Center's territory is many and varied. In most instances, the trend in use is upward and the appreciation of public forest lands by the public is being demonstrated. The demand for water has greatly increased; the demand for forest products is upward; livestock grazing has slowly

Figure 28.--Hunting is a favorite recreational activity.

declined; hunting and fishing have risen; and recreationists of all sorts have found increased satisfaction in visiting the Colorado National Forests.

All these demands create problems of land management; problems which center around the maintenance of the forest resource so that it will remain in balance with its environment and its use.

PROBLEMS AND THEIR SIGNIFICANCE

Problems stemming from the physical characteristics of the Center's territory associated with the use to which the lands are subjected, are interrelated. They are not easily separated, for the problems centered around a single use have a modifying effect on one another. Yet, for the purpose of clarity, it appears desirable to discuss the problems and their significance as individual entities. An attempt will be made to point out where certain problems of one discipline overlap into that of another.

In Forest Management

The lack of basic knowledge of site capabilities within the Engelmann spruce-subalpine fir, lodgepole pine, aspen, and ponderosa pine types has hampered the management and silviculture of all forest species. This lack extends to the physiology, growth habits, and reproduction of all forest species on different soils, exposures, and elevations.

Other major problems within the forest lands of the Center's territory are:

1. How to harvest inaccessible mature, overmature, and decadent stands of spruce-fir and lodgepole pine timber.

2. How to manage old-growth, cutover, and improperly stocked spruce-fir-lodgepole and ponderosa pine forests for maximum timber production. (Fig. 29)

3. How to develop greater utilization of wood supplies available in beetle-killed and old-growth spruce-fir-lodgepole and ponderosa pine forests. (Fig. 30)

4. How to obtain Engelmann spruce reproduction where old-growth spruce has been beetle-killed or harvested.

The trend in the use of forest products is upward. The significance of the above problems is one of meeting, on a sustained-yield basis, both present day and future demands for these products. Of equal importance is the establishment of young forests which may be more easily managed to the end that more timber per acre will result. Associated with the problems of forest management are those of watershed management and recreation. The influence which solutions of forest management problems has on these other two important uses may or may not restrict their widespread application.

Figure 29.--How to manage cutover forest stands.

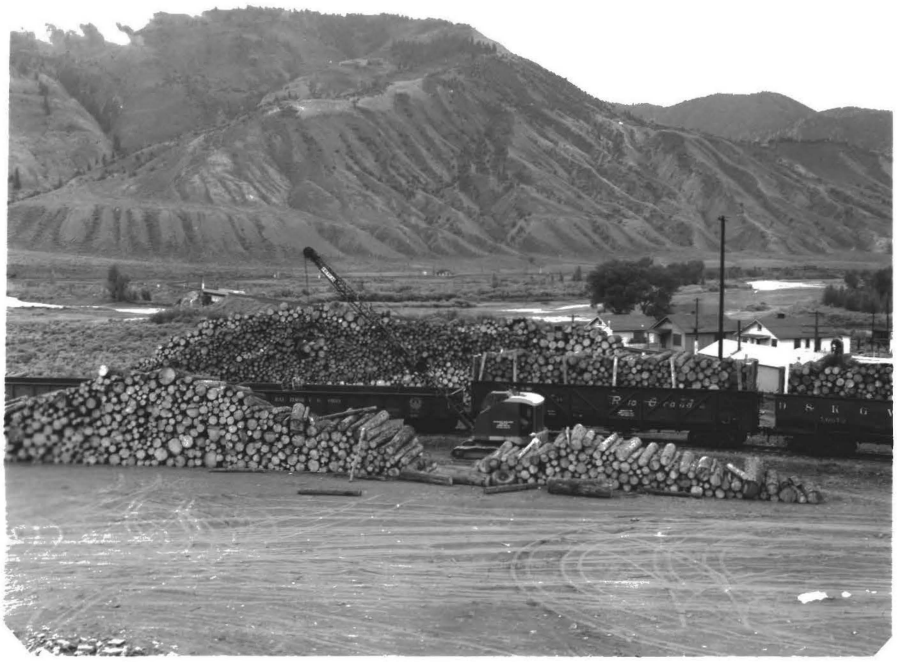

Figure 30.--How to develop greater utilization of wood supplies.

In Range and Wildlife Management

The absence of basic information of the reaction of various forage plants to different degrees of grazing by livestock and game on different soils, slopes, and exposures has retarded the adoption of improved range practices in the ponderosa pine-bunchgrass type, and alpine grasslands. Fundamentals of plant ecology are likewise lacking which would prove helpful in the extension of desired range and wildlife practices.

Other major problems of the grazing lands of the Center's territory are:

1. How to obtain maximum livestock production on ponderosa pine-bunchgrass, and alpine ranges, consistent with wise management of other resources. (Fig. 31)

2. How best to use improved ponderosa pine-bunchgrass ranges for greater returns in livestock and water yields.

3. How to resolve conflicts of grazing competition between deer and elk, and domestic animals. (Fig. 32)

The trend in livestock use of the ranges within the mountain portion of the Center's territory is downward. This in no way reduces the significance of the above problems because the ranges which are now used are generally suitable for livestock and game. In addition, the decline in livestock use pertains to public lands only and not to adjoining private lands that are still subject to

Figure 31.--How to obtain maximum livestock production on native ranges.

Figure 32.--How to resolve conflicts between game and livestock grazing the same area.

heavy grazing. In the past, livestock grazing has been associated with the depletion of range lands through accelerated surface runoff, sheet and gully erosion. Management of such depleted ranges or their improvement through seeding and planting will influence both water yields and recreational activities. The division of the forage crop on lands suitable for both livestock and game grazing will enhance the productive value of these lands. As the depleted rangelands improve, it will be important to know what range and wildlife practices to employ so that they will remain in their improved condition.

In Watershed Management

As a new science, watershed management requires more general knowledge of the hydrological characteristics of a variety of mountain streams, of different soils, of different exposures, and of the different climatic factors affecting runoff, snow accumulation and melt. In addition are needed methods of measuring erosion and sedimentation from slopes and stream channels of different land forms, geological materials, and soils.

Other major problems of the forest and rangelands within the Center's territory are:

1. How to increase water supplies and lengthen period of peak runoff from alpine grasslands, spruce-fir-lodgepole pine-aspen and ponderosa pine forests to meet increased demand. (Fig. 33)

Figure 33.--How to increase water supplies from spruce-fir, lodgepole pine forests.

2. How to increase snow accumulation and reduce melt and evaporation losses from the snow pack for increased water production.

3. How to integrate range and timber uses with maximum high-quality water production.

4. How to minimize floods and sedimentation damages from cloudburst storms in the ponderosa pine-bunchgrass type. (Fig. 34)

The demands for water from the high-elevation forests of the Center are on the increase. The significance of the above problems is one of meeting these demands in so far as it is possible by manipulating the native vegetation consistent with the maintenance of the soil resource. Problems of watershed management stem from the influences forest, range, wildlife, and other management practices have when applied to the land. This includes a wide variety of engineering structures designed to retard floods and sedimentation and to impound water for domestic, irrigation, power, and industrial uses. Water of high quality is at a premium and, as a result, it is important to restore depleted watersheds so that domestic water supplies will be enhanced. Improved watersheds will also aid materially in meeting the recreation impact on mountain lands. Management of watersheds for maximum water values may prove incompatible with management for maximum timber, range, and recreation values. Of

Figure 34.--How to minimize flood and sediment damage from cloudburst storms.

future significance will be the determination of points of compromise so that the optimum values of the entire resource will result.

In Recreation

Many of the physical problems connected with recreation are part of other management techniques. There are the problems of timber harvesting, range and wildlife management, watershed management and rehabilitation. Such problems do not touch upon the sociological phase of recreation. They do not consider opinion or behavior surveys, incentives for recreation or public desires for recreational improvements. The sociological phases of recreation are important in evaluating all other uses of forest resources.

Other major problems of recreation use are:

1. How to adjust to increased recreation pressures on ponderosa pine, spruce-fir-lodgepole-aspen and alpine areas for maintaining desirable water, timber, range and wildlife production. (Fig. 35)

2. How to determine the "carrying capacity" of lands for different kinds and concentrations of recreational use under various conditions of soil, topography, vegetation cover, forest age classes and stand densities.

The trend in recreational use of forest lands is sharply upward. The significance of the above problems is one of meeting both present day and future demands without sacrificing other important uses of

Figure 35.--How to adjust to increased recreation pressures.

the mountain lands. Some of the important considerations are the effects of recreational use on production of water, forage, and timber. Also interrelated is the effect of grazing, logging, road building, and industry on recreational values. The impact of recreational use is significant in terms of its effect on physical, biological, esthetic, and inspirational features of areas which are set aside for recreation.

In Forest Economics

Present day economic procedures do not apply to the measurement of social and economic benefits of forest land management. Too much dependence is now placed upon the value of products of the land far removed from their original source. The development of methods and procedures of measurements is of first importance.

Other major problems are:

1. How to determine the economic aspects of multiple resource management. (Fig. 36)

2. How to determine the economic feasibility of sound range management of ponderosa pine-bunchgrass and alpine grassland ranges.

3. How to determine land values where timber harvesting has been undertaken to increase water yields.

Figure 36.--How to determine the economic aspects of multiple resource management.

4. How to determine recreational benefits in terms of multiple resource management.

In general, the trend in use of the mountain portion of the Center's territory is upward. As all uses increase in intensity, conflicts will arise as to which one should be given priority. A measure of the economic values and benefits of individual uses, and in combination, will prove helpful in resolving these conflicts. Of additional importance will be the economic evaluation of structural and other improvements placed on the land for the purpose of curtailing flood flows, excessive erosion, and sedimentation from cloudburst storms. Surveys of recreational costs and benefits will be of significance in meeting the upsurge of visits to Colorado National Forests.

ATTACK ON PROBLEMS

Within the Center's territory are located the Fraser and Manitou Experimental Forests. (Fig. 1) Forest and Range Research was initiated at these experimental forests in 1936 and 1937. Numerous research results have been published and reported on. These results have been applied, where feasible, for the improvement in forest land management. Specific details and references to the research results may be found in the Specific References cited at the end of this report.

Because of the need to meet the demands placed upon several resources by many people, the Center must provide much greater skill in drawing up research objectives than is required in single resource research. Objectives are here a complex composite that must be brought into a correct balance by great skill and insight in order to assure that the goal is the achievement of the greatest good. They are the key to successful multiple resource research. Poorly conceived, they can result in much work on costly projects that produce little or no results applicable to many-sided problems.

The solution of resource management problems at the Fort Collins Research Center does not end, as is customary, with the determination of the methods of management which will accomplish the most for a given resource. This is but the starting point because maximum forage production and its optimum utilization may result in excessive sedimentation, maximum streamflow in forest depletion, maximum timber production in low water yield, and, even though management practices for maximum water and timber yields should prove to be compatible, they may easily be incompatible with objectives of recreation. The real solution is attained only when it is learned how several resources can best be managed harmoniously to produce the greatest good for the greatest number in the long run. In short, what is needed n each instance is an integrated answer that gives appropriate consideration to the demands made upon each resource.

The Fort Collins Research Center's attack on problems is summarized under Past Work and Contemporary Work.

Past Work

The major research results to date have been helpful in the management of the forest lands within the Center's territory. (Fig. 37) For example, recent trials of the overhead cable logging system installed in the spruce-fir-lodgepole pine type at the Fraser Experimental Forest, on slopes ranging from 30 percent to 80 percent, have demonstrated the feasibility of this system of logging in the central Rocky Mountains. Some 3 million acres of mature and overmature stands of timber previously considered inaccessible can now be logged with this system. Because the overhead cable logging system requires only a few miles of road for its operation, costs per thousand board-feet of timber delivered at a landing will be from $3.00 to $5.00 less than the cost for the conventional system of logging which embodies the use of horses, skid trails, and a series of logging roads.

Another contribution by forest management research is the development of the alternate-strip clear-cutting system in spruce-fir-lodgepole pine. This system is an outgrowth of tests at the Fraser Experimental Forest and elsewhere in the type. Initial tests of this system included clear-cutting strips, 66 feet wide, alternated with uncut strips of the same width. This system was compared with two other systems of cutting; namely, group selection where trees were removed in small circles, and single-tree selection where the trees were uniformly cut over an area. Windthrow after logging

Overhead Cable Logging System Spruce-Fir-Lodgepole Pine
Increased Water Yields Through Timber Harvesting Spruce-Fir-Lodgepole Pine
Alternate-Strip Clear Cutting System Spruce-Fir-Lodgepole Pine
Decreased Soil Water Absorption Through Cattle Grazing Ponderosa Pine Ranges
Major Research Results Todate
Forest Management
Watershed Management
Range Management
Optimum Cattle Use Improved Ponderosa Pine Ranges
Optimum Cattle Use Ponderosa Pine Ranges

Figure 37.--Major research results of the Fort Collins Research Center.

accounts for the greatest loss in timber growth. Although severe in the alternate-strip clear-cutting system, it is not as severe as in the single-tree selection system. It appears that the uncut strips tend to break the force of the wind and reduce windfall losses. Increased water content of snow in the 3 types of cutting amounted to about 22 percent and was related more to the amount of timber removed (60 percent) than to the method by which it was harvested.

An outstanding study at the Manitou Experimental Forest has been the results of different degrees of grazing intensities on reseeded pastures. Pastures reseeded to crested wheatgrass, brome grass, Russian wildrye, intermediate wheatgrass, and a mixture of smooth brome and crested wheatgrasses have, over the years, provided more forage and greater livestock gains than adjacent native pastures. Studies establishing the severity to which these introduced grasses may be grazed are important. For example, grazing use which leaves less than a 2-inch stubble height will injure a stand of smooth brome. Results from other species show that Russian wildrye and crested wheatgrass are much more resistant to heavy grazing than either brome or intermediate wheatgrass and that more care must be taken in the management of the latter.

Another important study at the Manitou Experimental Forest is concerned with the effects of different degrees of grazing intensity on native bunchgrass ranges of the ponderosa pine-bunchgrass ranges. That grazing intensity which removes from 35 percent to 40 percent of the current season's growth of the native bunchgrasses, Arizona

fescue, and mountain muhly, has been determined to be the optimum use for these particular ranges. This use has produced continued high cattle gains of 225 pounds per head for a 5-months season, which is about 70 pounds more per head per season than from the cattle on the more heavily grazed pastures. This optimum intensity of grazing has also maintained the forage yield of the important grasses and has given the highest returns per section of land.

At the Manitou Experimental Forest, cattle grazing has reduced water absorption by the soils when compared to non-use. The results of a study carried on over the years from 1941 to 1954 show that all grazing intensities employed at the experimental forest reduced the water absorption rates of the soils. For example, when compared with no grazing, light grazing reduced water absorption by .76 inches; moderate by 1.06 inches; and heavy by 1.31 inches. The study showed that litter accumulation on the soil surface and trampling were the two main factors governing the water absorption rate and that cattle grazing influences these two factors.

An important study at the Fraser Experimental Forest is concerned with the effect on water yield through the harvesting of spruce-fir-lodgepole pine timber. The streamflow of two experimental watersheds was compared for a number of years. Following this calibration period, the timber on one of the watersheds, Fool Creek, was harvested according to the alternate-strip clear-cutting system. Clear-cut strips from 66 feet to 398 feet in width were employed.

A total of about 3,560,000 board-feet of timber products have been removed from the watershed. This represents about half of the original volume. The harvesting of the timber on Fool Creek showed a 37 percent increase in streamflow, based on one year's record; the period of peak flow was also altered. The annual water yield from the Fool Creek watershed has amounted to 13 inches and provides a good index of the water yielding capacity of the forest lands between 9,500 feet and 11,500 feet.

Contemporary Work

The organization of the Fort Collins Research Center is based on several research disciplines. (Fig. 38) These disciplines deal with specific problems in the various fields of forest land management. The integration of the research results of these various fields into multiple use research comes through the office of the research center leader.

The outline which follows summarizes present research activities and the proposed expansion of these activities. All activities are designed to attack the major problems in whole, or in part.

Forest Management

Silviculture

I. Continue and intensify studies already in progress. The more comprehensive of these are:

project leaders

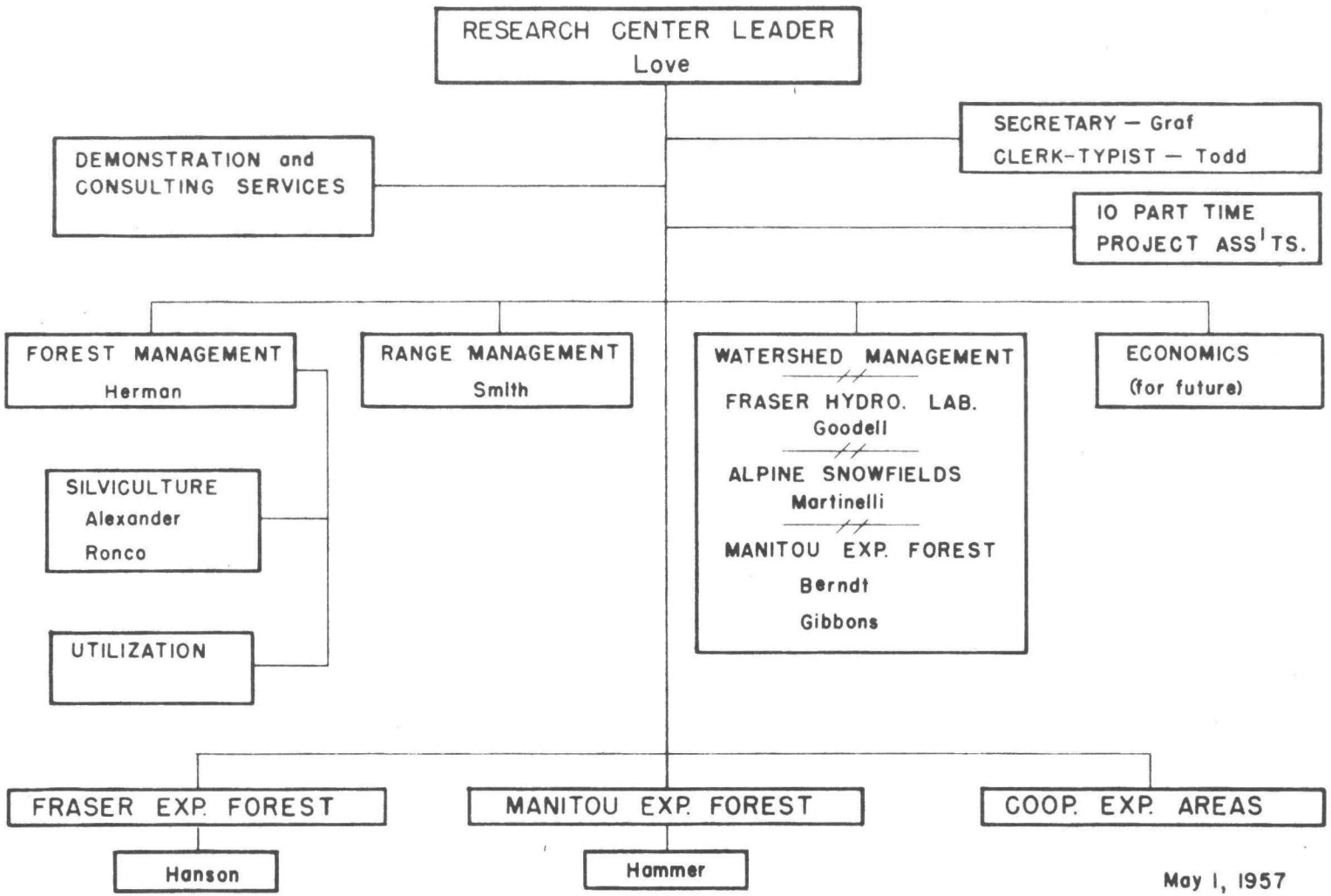

Figure 38.--Organizational chart, Fort Collins Research Center.

A. Determining for the Engelmann spruce, alpine fir, and lodgepole pine types the best silvicultural systems from the standpoint of natural reproduction, volume increment, mortality, control of damaging agents, and water yield and the modification of the systems necessary to meet the needs of efficient cable logging.

B. Developing for young even-aged stands of Engelmann spruce, alpine fir, and lodgepole pine profitable methods of cutting selected merchantable trees to improve the composition, quality, growth, and health of the remaining trees.

II. Proposed expansion:

A. Extend the silvicultural systems developed for the logging of lodgepole pine and spruce-fir stands to other areas outside of the Fraser Experimental Forest.

B. Prepare for trials of a cable logging system in the harvesting of lodgepole pine and Engelmann spruce in the steep mountain terrain.

C. Determine for the ponderosa pine type the best silvicultural system of integrated management for timber production and forage production.

Utilization

I. Continue and intensify studies already in progress. The more comprehensive of these are:

A. Introduce more economical and efficient methods of harvesting timber stands of low per acre volume in the steep high-altitude types having high water yielding values.

B. Develop profitable outlets for small stem material now being lost to natural mortality.

C. Introduce economical means of removing and using low value tree species that are competing for higher value land uses.

D. Establish a pilot plant demonstration of the operation of the cable logging system to the harvesting of high-elevation forests of the central Rocky Mountains.

II. Proposed expansion:

A. Expand the trials of the use of the cable logging system to the harvesting of timber on other areas both within and adjacent to the Fraser Experimental Forest.

B. Intensify the dissemination of information on the use of the cable logging system to the harvesting of timber in steep mountain watersheds.

Range Management

I. Continue and intensify studies already in progress. The more comprehensive of these are:

A. Develop and test grazing systems adapted to the requirements and conditions of the ponderosa pine-bunchgrass type and conducive to the most efficient utilization of the forage by livestock consistent with the maintenance or improvement of the native forage resource, soil and watershed values and other resources.

B. Determining for the ponderosa pine-bunchgrass type improved by various practices, the optimum seasons, intensities, and systems of grazing for obtaining maximum sustained grazing returns and other benefits from the important species used for reseeding in various localities and determining how the use of improved range and of native range can best be integrated for the greatest total benefit in the ponderosa pine-bunchgrass type.

C. Developing objective criteria useful to range managers for judging present condition and productivity of livestock ranges in the ponderosa pine-bunchgrass type in relation to potentialities and for determining whether the ranges are improving or deteriorating.

II. Proposed expansion:

A. Initiate survey of alpine and subalpine sheep ranges and begin sheep grazing management studies in these zones.

B. Determine appropriate seasons of grazing and optimum degrees of utilization for obtaining maximum sustained yield of nutritious forage and livestock products for ponderosa pine-bunchgrass ranges.

C. Select and establish watershed areas which may be used to determine the effects of proper grazing management on run-off and erosion in the ponderosa pine type.

D. Initiate studies of the relation between livestock and big game grazing animals where both are dependent upon the same range for summer and winter feed.

Watershed Management

I. Continue and intensify studies already in progress. The more comprehensive of these are:

A. Determining the storage and movement of water within the soil as influenced by plant cover and management.

B. Determining the influence of soil characteristics, physiographic, climatic, and biologic factors upon the soil stability.

C. Determining evapo-transpiration for various plant cover types and the influence of plant density and management practices upon soil moisture and streamflow.

D. Determining the effect of vegetation upon water yields, flood peaks, water quality, and the seasonal distribution of streamflow.

II. Proposed expansion:

A. Determine the effects of livestock grazing on runoff and erosion in the ponderosa pine-bunchgrass type.

B. Develop better practices for restoring land whose productivity has been lowered by past poor management. This includes the development of necessary gulley erosion control structures and plantings.

C. Evaluate the water yielding characteristics of the alpine and subalpine types to determine the influence of sheep grazing on erosion and water yield from these types.

Hydrologic Laboratory

I. Continue and intensify studies already in progress. The more comprehensive of these are:

A. Determining the effects on streamflow through the harvesting of lodgepole pine and spruce-fir timber (Fool Creek watershed).

B. Determining the effects of logging road construction on snowmelt runoff and soil erosion in the lodgepole pine and spruce-fir type (Fool Creek watershed).

C. Determining the effect of different widths of strip cutting in the lodgepole pine-spruce-fir type on the accumulation of snow (Fool Creek watershed).

II. Proposed expansion:

A. Intensify the dissemination of research results already obtained at the Hydrologic Laboratory.

B. Initiate studies of a fundamental nature concerned with snow interception and accumulation, snowmelt and evaporation, and the movement of snowmelt waters through the soil to the stream channel.

C. Intensify measurements concerned with the effects of different silvicultural systems and logging practices on streamflow and water yield in the spruce-fir and lodgepole pine forests.

Forest Recreation

I. At the present time, no studies are in progress.

II. Proposed expansion:

A. Conduct studies pertaining to the "carrying capacity" of both established and new recreational areas.

B. Initiate studies on the effects of recreational use on production of water, forage, and timber.

C. Conduct studies on the recreational benefits of rehabilitating depleted watersheds from the standpoint of improving game and fish habitats.

D. Initiate opinion and behavior surveys to determine public desires for recreational-use areas.

Forest Economics

I. At the present time, no studies are in progress.

II. Proposed expansion:

A. Conduct studies pertaining to the economic aspects of multiple resource management.

B. Conduct time studies of the cable logging system to determine its economic feasibility for adoption by local logging operators.

C. Initiate studies in the economics of proper range management for the ponderosa pine-bunchgrass ranges and for the alpine and subalpine ranges.

D. Initiate studies as to the increased value of areas where timber harvesting has been undertaken to increase water supplies.

Demonstration

Develop and execute a program for the dissemination of research results at the Manitou Experimental Forest, the Fraser Experimental Forest, and cooperative experimental areas. This will be accomplished by means of guided tours, distribution of popular pamphlets, illustrated lectures, and organized training schools. Particular effort will be made to place before the public the research results of the Hydrologic Laboratory as these results will be fundamental to an understanding of the processes involved in improving water yields through snow management. Likewise, considerable effort will be made to currently summarize and bring to public attention the advantages of the cable logging system for harvesting timber from steep mountain watersheds.

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